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Doctor Custos, Doctor Opponent, ladies and gentlemen,

Why do some novelties become widely adopted in markets and in society, while some others fail to do so? And more importantly, what can be done to develop innovations successfully? During the last years, I have worked together with my colleagues in order to create new and better methods in order to answer these questions.

The starting point of the work has been the recognition that we need tools and methods for future oriented impact evaluation. This means that we need to be able to foresee the potential impacts of different actions instead of just using trial and error learning. Trial and error works very well for many problems in our everyday life. In general, people can learn how to act when they receive accurate feedback whether their past actions were appropriate.

In other cases it is more difficult to learn from experience, either from your own or those of others. Related to the development of a new innovation, for instance, it can be difficult to know how a particular action, such as a single development project or a marketing campaign ultimately affects. In addition to long time delays, different actions may reinforce or counteract each other. Also, the short and long term consequences might differ. Under these conditions, we need some other means, such as modelling, in order to learn the best courses of action.

A model is a simplified and formalised representation of a part of the real world. For example, a map is one type of model that we can use to find our way in unfamiliar terrain. In the field of systems analysis, models are often expressed using mathematics. In my dissertation, the particular modelling methodology that I use is called system dynamics, which is an approach that began with the work of Jay Forrester in the 1950's. As its name implies, the focus is on dynamic behaviour, that is, how the behavior of a system changes through time.

The methodology is based on the idea that in order to understand this behaviour, one needs to understand the interaction of different feedback loops and delays within the system.

Feedback loops can be visualised using diagrams that show the cause and effect relationships between different variables. One type of feedback loop is balancing feedback, which counteracts change from a target. A thermostat, for example, adjusts the temperature of a room to the desired level. Similarly, in markets there is a balancing feedback that involves prices, which adjust depending on supply and demand. Another type of feedback loop is reinforcing feedback, which amplifies changes. Depending on the desirability of the effect, these are also called virtuous or vicious cycles. Understanding a single feedback loop is quite straightforward, but it is much more difficult to understand the interaction of multiple simultaneous loops.

Besides feedback loops, it is also useful to distinguish between “stock” and “flow” variables in a system in order to understand delays between actions and consequences. The stocks determine what the state of a system is at a given point in time, and the flows determine how much the value of the stocks change. A simple example of a stock variable would be the amount of water in a bathtub, which is changed through in- and outflows to the tub. In a more complex system, the values of the flows would depend on the values of other stock variables. Consider an innovation system. In order to understand the rate of adoption of an innovation, one needs to consider many factors, such as the maturity level of a technology and the level of user’s awareness, both of which depend on yet other factors. Modelling an innovation system would involve specifying each of these causal links in detail.

Once a mathematical representation of a system has been constructed, it can be simulated using a computer. A computer simulation is a virtual world that imitates real life. An important distinction from real life is the possibility to quickly observe consequences that could take years to observe in real life, or which could be too dangerous or costly to test in real life.

Because of these issues, simulation environments are powerful tools to enhance learning and to design better policies for system improvement.

System dynamics modelling and simulation have been used to tackle a wide range on different issues. In many cases, it has been shown using simulations that well intentioned policies can, in fact, have unintended side effects that result in inefficient outcomes, or even make the system worse off. One classic example is Forrester's model on urban growth and decay, which also inspired the development of the Simcity computer strategy game. Another example, which is still still relevant today, is the work commissioned by the Club of Rome to tackle world wide environmental problems, and which showed how global population, industrial growth, and food production all interact with limited natural resources of the earth.

Some previous modelling studies have also examined different aspects of innovation processes, but there is much more potential for dynamic modelling in this area.

Innovations are new ideas or inventions that are put into practice in the form of new products, services, or processes. Innovations also bring about benefits to their developers and users. Traditionally, especially economic benefits have been emphasised. However, new innovations have much potential in solving urgent societal problems, such as climate change. The topic of my work is related to systemic innovations in particular. The word systemic emphasises interconnections between elements of a whole. The key idea behind systems thinking is that it is essential to take these interconnections into account, rather than analyse each part separately.

In the context of innovation, the word systemic thus highlights the importance of multiple, interrelated parts of a novelty that must work together in order to obtain desired benefits.

Consider, for example, new types of health care services that are being developed to tackle chronic illnesses. A new service concept could involve many differences compared to old ways of organizing health care, such as the development of digital e-health tools or segmenting patients based on their health needs. The type of interaction between these different parts affects how renewal processes should be carried out. One question is whether certain aspects of a new service can be tested and piloted in individual healthcare units, or whether the whole renewal should be planned and managed centrally.

Systemic innovations also involve changes in the wider environment, or innovation system, in which the novelties are developed. This is in contrast to incremental product innovation, in which new features can be added to an existing product, but the developing firm does not necessarily have to consider other issues, such as changes in distribution channels, or the creation of a completely new market for its offering.

Models can be useful in different ways. One way is to use a model to obtain theoretical insights that explain or predict similar patterns across different contexts. We know, for example, that the same mechanism that causes instability in supply chains also accounts for stop-and-go traffic that does not flow smoothly. Or that a prisoner's dilemma does not necessarily involve any actual prisoners.

In the field of innovation studies, it is recognised that new systemic innovations that challenge established ways of operating in society can face many problems. Many of these are related to path dependencies that favour old solutions. In the case of digital platforms, network effects and the role of data accumulation are particularly important. Network effects mean that the value of a product or service depends on the total number of users. For example, the value of a social media service increases with the number of users, as users can connect to more people. Because of this, in the early phases of platform development it may be difficult to attract users when the total number of users is still low.

Models can also guide us to make better decisions in specific cases. Whereas models that aim to generate theoretical insights are often kept as simple as possible, models for guiding decision making in specific cases need to be more descriptive and involve more details. In my dissertation, one goal of my work is to use modelling to analyse how to achieve the target of emission free urban transport in the context of the Helsinki metropolitan area. Another model in my work is related to showing the impacts of an environmental data platform that was developed in a Finnish research programme.

In addition to the use of models as such, the process of modelling is often useful. Modelling forces one to create a logically consistent representation of how a system behaves, which is useful for clarifying unstated assumptions regarding causes and effects. This is why modelling is also useful for facilitating communication between different people. Ordinary language often leads to many misinterpretations, which may be clarified when people are building models together. During the process, people also learn about others' perspectives, which may help them to see the big picture. Everyone involved does not need to be an expert modeller. Rather, system dynamics models consist of relations between causes and effects that can be understood without deep modelling expertise, and which can be later developed into mathematical representations.

It is worth remembering that every approach and method has its limitations, and this applies to system dynamics modelling as well. If all you have is a hammer, every problem looks like a nail. For simple problems, you need to identify the right tool for the purpose, either some type of modelling or some non-modelling activity. For more complex problems this is not enough, and a better way is to identify a set of tools and methods to be used. However, there is no ready textbook answer how this should be done.

In my dissertation, I have worked to combine the use of system dynamics modelling with tools from the fields of foresight and impact evaluation. The purpose of foresight is to create knowledge about possible future development paths, and often involves the use of various non-modelling tools. Particularly, interactive vision building activities can effectively complement system dynamics modelling in the early problem definition phase. Also, visual tools, such as roadmaps that illustrate different factors and activities, can be useful to gather information, which can be then be used as inputs to model building. Related to impact evaluation, a contribution of my research is related to combining the use of a multicriteria assessment framework with system dynamics modelling. The framework is used to categorise different types of impacts of an innovation, while system dynamics modelling is used to show how these different types of impacts are interrelated.

In practice, I have worked with other researchers from fields in which the use of mathematical modelling is not very common. During the process, I have learned that there are, actually, many similarities between seemingly disparate fields. One finding for me has been that systems thinking seems to appear in different forms within the fields of foresight as well as impact evaluation. There is no single right approach to studying systems. Rather, alternative viewpoints and interpretations can be valuable for systems modellers because they offer complementary insights, which may otherwise not be noticed. Complementary perspectives in addition to modelling can be especially helpful in order to obtain positive impacts through modelling and to achieve changes in real life systems.

This concludes my lectio praecursoria, which, I hope, makes it easier for the audience to follow the examination of my dissertation.

I ask you, professor Bob Walrave, as the opponent appointed by the Aalto University School of Science to make any observations on the thesis which you consider appropriate.